

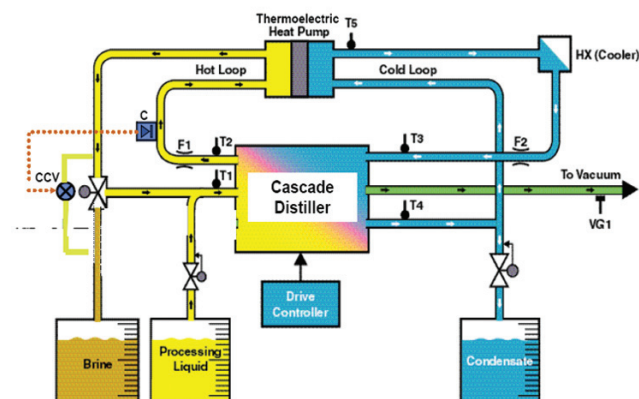
# Cascade Distillation Subsystem Development

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Recovery of potable water from wastewater is essential for the success of long-term human missions to the moon and Mars. Honeywell International, Morristown, N.J., and the Johnson Space Center (JSC) Crew and Thermal Systems Division are developing a wastewater processing subsystem based on centrifugal vacuum distillation. This wastewater processing cascade distillation subsystem (CDS) uses an efficient multistage thermodynamic process to produce purified water. The rotary centrifugal design of the system also provides gas/liquid phase separation and liquid transport under microgravity conditions. We built, delivered, and integrated a five-stage prototype of the subsystem into the JSC Advanced Water Recovery Systems Development Facility (AWRSDF) for development testing. The system, currently being tested at JSC, has been challenged with a variety of ersatz and human-generated waste streams representative of lunar outpost and transit mission wastewater.

A simplified schematic of the CDS is shown in figure 1. In general, operation of the CDS involves evaporation and



**Fig. 1.** CDS block diagram.

condensation of wastewater and brine within a rotating drum apparatus. The drum is divided into five distillation compartments by means of specially designed baffles. Influent feed and recycled brine solutions are fed into the rotating drum at various stages within the distillation process. The vapor formed within each distillation chamber is condensed on the surface of the partition opposite the next evaporation stage. Each of the five distillation compartments is maintained at successively lower

operating pressure, allowing the heat of vaporization to be recovered four times. To enhance the liquid evaporation process, we employed an external thermoelectric heat pump (THP) to provide heat energy to the hot side of the liquid recirculation loop. The THP also provides cooling energy to the cold recirculation loop used to remove the heat of vaporization not recuperated from the process. A trimming heat exchanger provides additional cooling energy to balance the thermal inefficiencies common to the THP technology. By operating at reduced pressure and recovering the latent heat of vaporization, we conserved the energy requirements of the CDS. In addition, the centrifugal forces produced during rotation of the drum assembly support the transport of all liquids within the system and the operation of the distiller at reduced gravity.

The CDS test stand, as integrated into the JSC AWRSDF, is shown in figure 2. We began performance testing of the CDS in September 6, 2007 and ended it July 29, 2008. Over the course of this testing, we processed in excess of 1,180 liters of influent feed solution through



**Fig. 2.** AWRSDF CDS test system.

the CDS in more than 120 batch runs. Logged hours in the laboratory exceeded 830, including over 400 hours of distiller operation. In total, we tested more than

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continued

10 influent feed streams, including deionized water, sodium chloride solutions, human- and ersatz-generated pretreated urine, human- and ersatz-generated humidity condensate, and mixed waste streams comprising solutions of a transit mission ersatz and solutions containing human-generated urine mixed with both human- and ersatz-generated humidity condensate.

The average water recovery over the course of testing was  $82\% \pm 8\%$ . We demonstrated recoveries as high as  $91.2\% \pm 0.7\%$  for specific test points on mixed waste streams. The

performance of the CDS was highly consistent and within acceptable limits for all test phases and test solution types. Based on these results, the system is now in development to support an Exploration Life Support (ELS) Project distillation comparison test begun in 2009. One of the project objectives was to reconfigure the system in support of the ELS comparison tests. We challenged the CDS, along with two other candidate distillation technologies, using a series of human-generated waste streams representative of those anticipated for a lunar outpost.